Burners for Glass Melting Furnaces

Neil Simpson, Eclipse Incorporated, USA

Introduction

In the late 1980's and early 1990's a consortium of gas utilities named NGNOX was formed to investigate the natural gas firing of glass tanks. The objective was to develop combustion firing techniques that would lower NOx emissions and improve the thermal efficiency of natural gas firing. The tests were performed at the former British Gas Coleshill site on their 40% scale port of an actual cross-fired regenerative furnace. The results of the consortium were presented by L.J.Korstanje and P.Martin [1]. Of greatest significance was the empirical establishment of the relationship between NOx and heat transfer. The lower the NOx, the higher the heat transfer. The higher the heat transfer by definition requires a lower amount of energy. The lower the amount of energy produces a lower amount of CO2 and total emissions. Lower total emissions result in smaller capital equipment and operating costs for post treatment abatement equipment such as electrostatic precipitators, bag house, scrubbers and SCR De NOx. This paper will focus on the methods of primary NOx reduction in a glass melting furnace.

Studies on High Temperature Low NOx Combustion for Glass Furnaces

L.J. Korstanje and P.Martin. Conclusions [1] and interpretation

The trials provided a realistic comparison between new burner designs and conventional oil and gas burners for regenerative glass furnaces. NOx emissions were in the range from 787 to 2854 ppm depending on burner design and fuel type. The heat flux to the hearth ranged from 79 to 96 kW/m2. The main conclusions of the burner tests were:

1. Single hole natural gas burners produce a relatively high NOx levels (2360-2820 ppm) and a low heat flux (79.5-85.2 kW/m2).
2. More complex natural gas burners such as the double impulse and multi-hole burner produce significantly lower NOx and show a better thermal performance than single hole burners.
3. The best results with natural gas were obtained with the British Gas multi hole burner. The burner combines a low NOx emission (787ppm) with a high heat flux (92.3 kW/m2).
4. The LPG burners show a relatively high NOx emission and a low heat flux similar to the single hole natural gas burners.
5. The performance of the HFO burners fell within the range found in the low NOx natural gas burners.
6. The performance of the mixed oil and gas burners depended very much on the oil/gas ratio. At and oil/gas ratio of 70/30 the highest heat flux to the hearth of all the tests 95.9 kW/m2 was achieved.

7 The results of the trials show that by changes in the design and operation of burners used in glass furnaces it is possible to reduce the NOx emission and simultaneously increase the heat transfer.

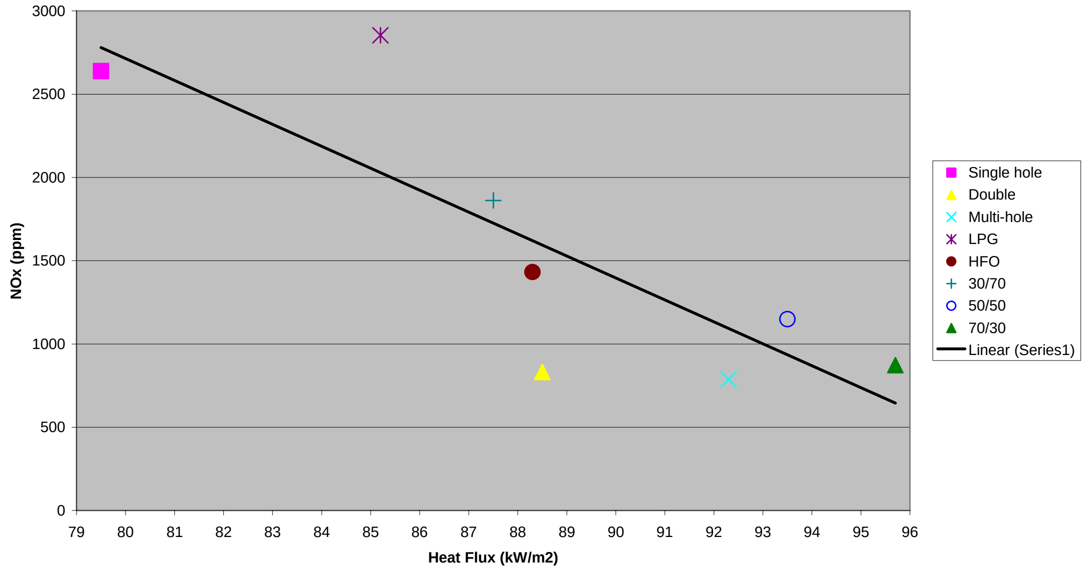


Fig. 1 BG data on heat flux v NOx 8° angle.

The results of the 8 degrees are shown in a graph [Figure1]. The addition of a trend line clearly shows that high NOx has low heat transfer. Conversely and more importantly to the glass industry low NOx burners have high heat transfer. By addressing the combustion requirements of the furnace as a whole it is possible to reduce NOx significantly. Provided there is no short-circuiting of flames lower NOx will increase heat transfer and lower energy usage. If there is a reduction in energy there is a corresponding reduction in CO2 emissions. Moreover there is a reduction in total emissions. Secondary, (out-with the furnace) abatement methods typically work on a volumetric basis. The lower the volume to be treated the smaller the device and therefore the smaller the capital required. Lower volumes require less energy for exhaust movement devices e.g. ID fans. In some cases [2] there has been reduction in urea usage in SCR de-NOx plants when a furnace has been converted to low NOx burners.

Eclipse Burners for Glass Furnaces

Eclipse is a global combustion company with burner manufacturing in 3 continents. The head quarters are located in Rockford Illinois and the company will celebrate its 100^{th} anniversary in 2008. In 1997, Eclipse bought Orlando based Combustion Tec, at that time the largest supplier of combustion equipment to the glass industry. In 2006 Eclipse purchased the intellectual property of Laidlaw Drew who was the second largest supplier. With the integration of the Combustion Tec and Laidlaw Drew portfolio of burners for the glass industry it is possible for Eclipse to demonstrate NOx reduction on all regenerative glass furnace port configurations: underport, sideport and throughport.

Step 1 – Seal the burners

The work performed by the consortium was on traditional underport burners where the burner (fuel injector) was positioned in the throat of a burner block with an annular air gap. When the burner was firing, this acted as a venturi and literally “sucked” cold air into the furnace and caused premature ignition of the fuel in some cases this air ingress is up to 5% of the total combustion air requirements. Therefore step 1 in NOx reduction is to seal the burners. Whether sideport or underport this can be achieved by one of three methods: water-cooled rings, windline air cooled socket plates or pressurized air cooled rings. In each case the operating principal is the same a metal seal or draught excluder is cooled by either water or air. This in turn conducts heat away from the burner and extends nozzle life. The type of seal used is determined by burner type and customer preference. When using a sealing device with a single hole style gas burner up to 48% NOx reduction is possible [2]. Energy reduction of 1-3% is typical. Figure 2 shows a Brighfire burner, bracket and block sealing with wind line cooling.

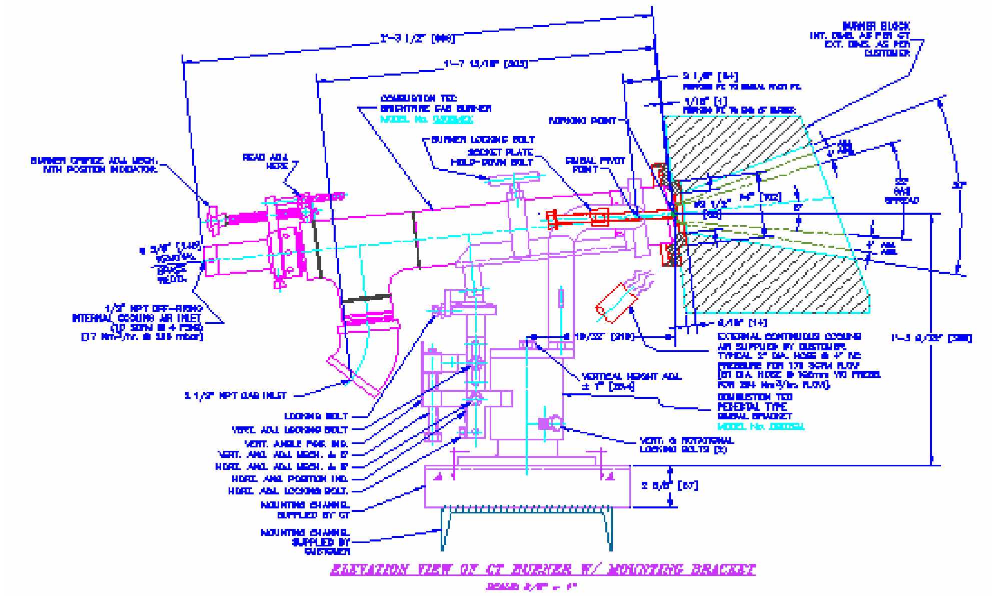


Fig. 2 Brightfire Underport Burner and Bracket Layout with Block Sealing Arrangement.

Steps 2 and 3 – Burner Selection and Resulting Flame Shape

This is essentially a combined step since the two are inextricably linked to produce the best flame coverage for maximum heat transfer. Typically underport and sideport burners use a dual impulse type of burner since this is conducive to a round burner block. Water-cooled throughport burners offer the potential to use a multi-hole technology.

Dual Impulse Style of Burners- Brightfire, WRASP-DI and GT-DI

The concept of a dual impulse burner is the use of two concentric gas streams. There is a high velocity inner nozzle surrounded by a lower velocity annular nozzle. In all 3 cases there is the ability to change the ratio of high velocity to low velocity gas. In the Brightfire case the burner is effectively a variable area device. By moving the relative position of the inner and outer nozzles there is the possibility to change the area of the annulus and therefore change the flows to adjust the rate of mixing and reduce NOx formation [3]. The WRASP-DI and GT-DI have the nozzle area fixed with the opportunity via a valve to change the volume of gas through the inner impulse and outer annulus. Figure 3 shows the effect of impulse on momentum. Figures 4 to 6 show the effect of high, medium and low velocities respectively.

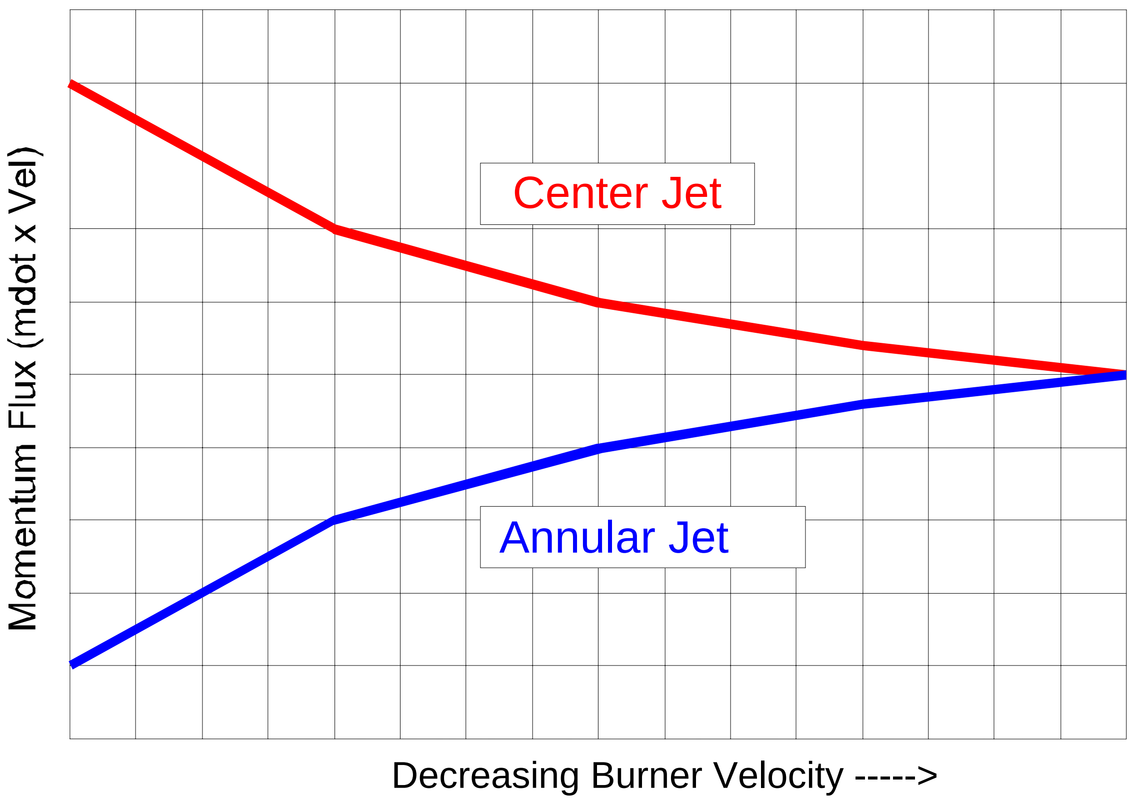


Fig. 3 Brightfire Burner Individual Jet Momentum Flux

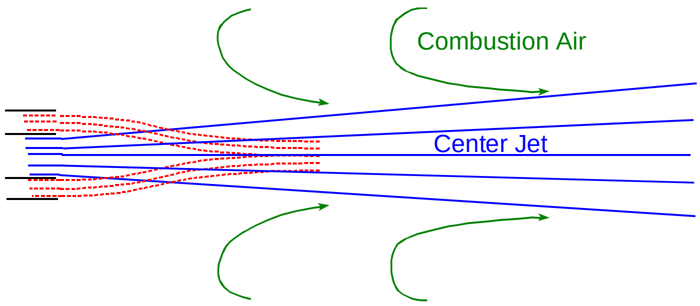


Fig. 4 Brightfire™ Burner Streamline Behavior at High Velocities

- Single cohesive gas jet
  - Rapid entrainment of combustion air by the gas stream within the melter
  - Short flame length
  - 10-15% lower NOx than annular type burner alone

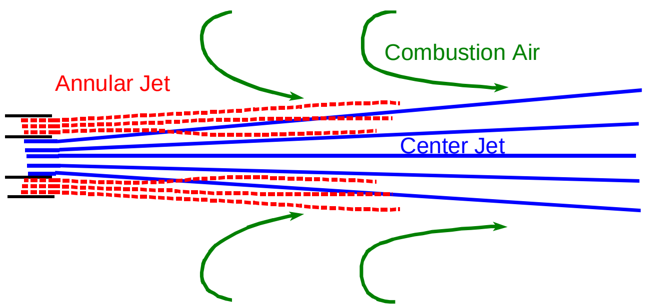


Fig. 5 Brightfire™ Burner Streamline Behavior at Intermediate Velocities

- Results:
  - Delayed mixing between gas and combustion air
  - Longer flame length
  - 25-35% lower NOx than annular type burner alone

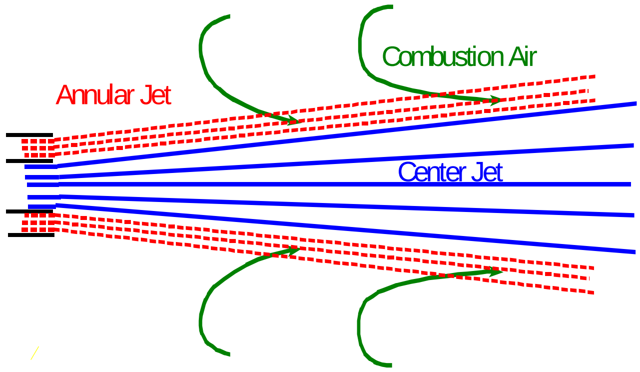


Fig. 6 Brightfire™ Burner Streamline Behavior at Low Velocities

- Results:
  - Creation of outer combustion zone with a central fuel core
  - Enhanced fuel cracking
  - Improved flame luminosity
  - Long bushy flames
  - 35-40% lower NOx than annular type burner alone

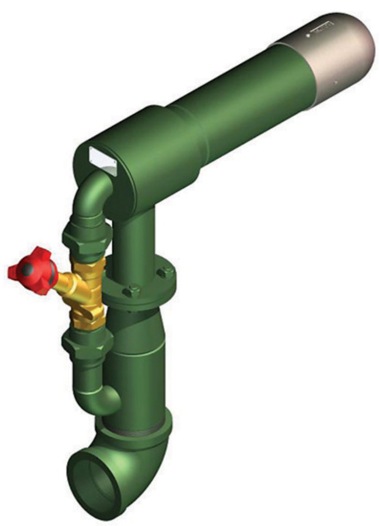


Fig. 7 WRASP-DI Side of Port Gas Burner

Figure 7 shows the WRASP-DI burner with the valve to adjust the proportion of gas to the inner high velocity impulse and lower velocity annulus.

Whether the burner type is underport or sideport each of the burner styles enables the flame shape to be changed. In each case a lower momentum flame with long bushy flames produces the lowest NOx. In cross-fired furnace applications an ideal visible flame is 60-80% of the furnace width. Short bright flames may have historically had the image of "good flames" however field experience indicates otherwise. High velocity causes more refractory damage than low velocity.

Multi-Hole Burners

Underport and sideport burners do not lend themselves to high capacity multi-hole burners due to space limitations. Water-cooled through-port burners have significantly more available area and can facilitate multi-hole nozzles. The WGD burner is shown in Figure 8.

Fig. 8 WGD Throughport Gas Burner

This water cooled burner is installed on a retraction mechanism for removal on the exhaust, non firing side. This is a flat flame burner created by the impingement of two series of jets. By changing the ratio of gas to the upper and lower nozzles it is possible to adjust the flame length and raise and lower the resulting flat flame. The BG data [1] would suggest that this burner would have the highest heat transfer for the equivalent NOx of a dual impulse burner. Unfortunately due to customer confidentiality there is presently no available NOx results for this burner. It has become one of the burners of choice for float manufacturers converting to natural gas from through-port oil.

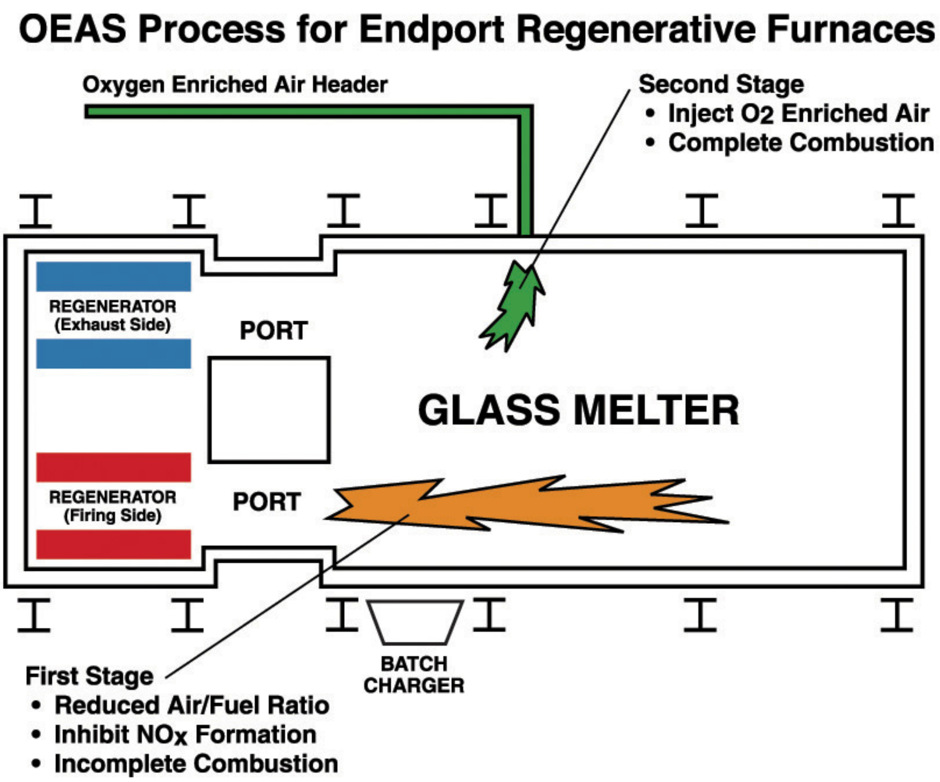
Oil and Gas Firing Burners

It has been demonstrated [1] and [2] that combined oil and gas firing can provide the lowest NOx and highest heat transfer. There are numerous installations of the Brightfire and GTOG version of this burner. For the majority of cases oil firing is now cost prohibitive and is used mainly in a back-up situation.

Step 4 – Optional OEAS in Furnace De-NOx

Depending on the results of the previous 3 steps and local environmental regulations the sealed staged burners will ideally meet NOx requirements. For countries which are not mandating the installation of post furnace SCR de-NOx abatement there is the option of further reducing NOx by using the Oxygen Enriched Air Staging [OEAS]. This is a furnace staging technique where the ports run close to or sub stoichiometric. The balance or excess of air or air enriched with oxygen is injected on the exhaust side to complete combustion prior to entering the regenerators. Unlike other De-NOx methods the process is inside the furnace and does not risk damage to refractory inside the furnace or regenerators. The simplest application of this technology is on an end-fired furnace.

This technology is seen as an alternative De-NOx device for traditional European container plants which typically do not have the real estate space for this equipment. The use of air only staging can reduce NOx by 35 to 75%.



Conclusions

The British Gas work has shown the relationship between NOx and heat transfer. The lower the NOx the higher the heat transfer. By sealing burners and utilizing either dual impulse or multi-hole burners there can be significant reduction in NOx and corresponding increase in heat transfer. Increase in heat transfer lowers energy, CO2 and total emissions resulting in smaller abatement devices and lower operating costs.

References

[1] L.J. Korstanje and P.Martin, Studies on High Temperature Low NOx Combustion for Glass Furnaces, Combustion and Emission Control II

[2] N.G.Simpson, Field Trials on High Temperature Low NOx Combustion for Glass Furnaces, Combustion and Emission Control III

[3] A. McIver, Ernie Curley, Richard Valtierra and Pat Wilson, Installation of a New Burner in a Float Furnace, Glass Problems Conference 2001

Neil Simpson, Glass Industry Manager Europe, 13 Roman Way Business Park, Droitwich Spa Worcestershire, WR9 9 AJ, tel. +44 789 435 3301, fax +44 1905 794923, e-mail: nsimpson@eclipsenet.com, www.eclipsenet.com